

## **CLAIMS**

### **We claim:**

1. A method for forming a copper interconnect having a robust copper barrier layer, the method comprising:

providing a substrate having an insulating layer and an opening in the insulating layer configured to receive an inlaid conducting structure;

forming a copper seed layer on the insulating layer and in the opening; implanting the seed layer with barrier material ions to form an implanted seed layer;

forming a bulk copper-containing layer on the implanted seed layer; and

annealing the substrate, so that the barrier material ions migrate through the seed layer to an interface between the seed layer and the insulating layer to form a final barrier layer.

2. The method of Claim 1 wherein the insulating layer is comprised of a low-K dielectric material.

3. The method of Claim 1 wherein implanted barrier material ions consist of ions selected from ions in the group: palladium, chromium, tantalum, magnesium, and molybdenum.

4. The method of Claim 2 wherein implanted barrier material ions consist of ions selected from ions in the group: palladium, chromium, tantalum, magnesium, and molybdenum.

5. The method of Claim 1 wherein forming the bulk layer of copper-containing material comprises electroplating the copper containing material onto the seed layer.

6. The method of Claim 1, wherein forming the bulk layer of copper-containing material comprises electroless deposition of the copper-containing material onto the seed layer.

7. The method of Claim 1, wherein the opening is a via.

8. The method of Claim 1, wherein the opening is a trench.

9. The method of Claim 1, wherein the opening is a combination of a trench overlying a via.

10. A method for forming a copper interconnect having a robust copper barrier layer, the method comprising:

providing a substrate having an insulating layer and an opening in the insulating layer configured to receive an inlaid conducting structure;

forming at least one barrier layer on the insulating layer and in the opening

forming a copper seed layer on the at least one barrier layer;

forming a bulk copper containing layer on the seed layer; and

annealing the substrate.

11. The method of Claim 10 wherein the insulating layer is comprised of a low-K dielectric material.

12. The method of Claim 10 wherein forming the at least one barrier layer comprises:

forming a first barrier layer on the insulating layer and in the opening; and

forming a second barrier layer on the insulating layer.

13. The method of Claim 12 wherein the first barrier layer is comprised of a tantalum-containing material.
14. The method of Claim 13 wherein the tantalum-containing material is selected from among tantalum and tantalum nitride.
15. The method of Claim 12 wherein the second barrier layer consists of a material selected from the group: palladium, chromium, tantalum, magnesium, and molybdenum.
16. The method of Claim 10 wherein, prior to the steps of forming the bulk copper containing layer and annealing the substrate, are the further steps of:
  - implanting the seed layer with barrier material ions to form an implanted seed layer;
  - wherein the step of forming a bulk copper-containing layer includes forming the bulk copper-containing layer on the implanted seed layer; and
  - wherein the step of annealing the substrate includes annealing the substrate, so that the barrier material ions migrate through the seed layer to the interface between the at least one barrier layer and the copper seed layer to form a final barrier layer.
17. The method of Claim 16 wherein implanted barrier material consists of a material selected from the group: palladium, chromium, tantalum, magnesium, and molybdenum.
18. The method of Claim 16 wherein forming the at least one barrier layer comprises:
  - forming a first barrier layer on the insulating layer and in the opening; and
  - forming a second barrier layer on the insulating layer.

19. The method of Claim 18 wherein:

the insulating layer is comprised of a low-K dielectric material;

the first barrier layer is comprised of material selected from among tantalum and tantalum nitride;

the second barrier layer consists of a material selected from the group: palladium, chromium, tantalum, magnesium, and molybdenum; and

the implanted barrier material ions consist of ions selected from the group of ions: palladium, chromium, tantalum, magnesium, and molybdenum.

20. The method of Claim 10, wherein forming the bulk layer of copper-containing material comprises electroplating the copper containing material onto the implanted seed layer.

21. The method of Claim 10, wherein forming the bulk layer of copper-containing material comprises electroless deposition of the copper containing material onto the implanted seed layer.

22. The method of Claim 10, wherein the opening is a via.

23. The method of Claim 10, wherein the opening is a trench.

24. The method of Claim 10, wherein the opening is a combination of a trench overlying a via.

25. A method for forming a copper interconnect having a robust copper barrier layer, the method comprising:

providing a substrate having an insulating layer and an opening in the insulating layer configured to receive an inlaid conducting structure;

forming a first portion of a copper seed layer on the insulating layer and in the opening;

forming an inter-layer barrier layer of barrier materials on the first portion of the copper seed layer;

forming a second portion of a copper seed layer on the inter-layer barrier layer;

forming a bulk copper-containing layer on the second portion of a copper seed layer; and

annealing the substrate, so that the barrier materials migrate through first portion of a copper seed layer to form a final barrier layer at the interface between the seed layer and the insulating layer.

26. The method of Claim 25 wherein barrier material consists of a material selected from the group: palladium, chromium, tantalum, magnesium, and molybdenum.

27. The method of Claim 25 wherein the insulating layer is comprised of a low-K dielectric material.

28. The method of Claim 25, wherein prior to forming the first portion of a copper seed layer, at least one barrier layer is formed on the insulating layer and in the opening and wherein the first portion of the copper seed layer is formed on the at least one barrier layer.

29. The method of Claim 28 wherein forming the at least one barrier layer comprises:

forming a first barrier layer on the insulating layer and in the opening; and

forming a second barrier layer on the insulating layer.

30. The method of Claim 29 wherein the first barrier layer is comprised of a tantalum-containing material.

31. The method of Claim 30 wherein the tantalum-containing material is selected from among tantalum and tantalum nitride.
32. The method of Claim 29 wherein the second barrier layer consists of a material selected from the group: palladium, chromium, tantalum, magnesium, and molybdenum.